Precision Engineering at LLNL

Precision engineering, including manufacturing and metrology, has underpinned the DOE physics mission at LLNL.

The technology developed in that support has flowed into U.S. industry and other government organizations.

While supporting LLNL's national security mission will always be our highest priority, we will continue to nurture synergistic relationships with industry and government.

UCRL-PRES-149549

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

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Precision Engineering History at LLNL

- Founded as the Metrology Group in the 1960s with the mission to reduce inaccuracies in the manufacturing of weapon's components.
- The approach developed was one of *determinism*, based on the simple fact that every part error had an associated error source that could be mitigated, controlled or isolated.
- The first application of this methodology was to improve the accuracy of the parts from tracer lathes. This required metrology improvements in the fabrication of the templates and then in the machines to get faithful reproduction of the shapes.
- Through history, the Precision Engineering Group has developed machines and processes to make components for LLNL's physics projects and nationally important programs.

The Precision Inspection Shell Measuring Machine, showing a calibration block, demonstrates capability to measure internal and external contours of axisymmetric parts to sub-micron uncertainty.

Precision Engineering at LLNL envelops a broad spectrum of capabilities & projects

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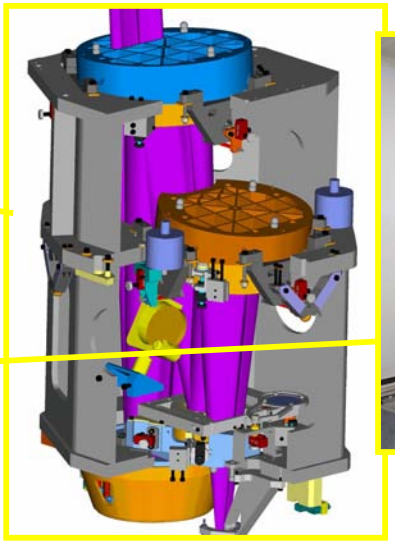
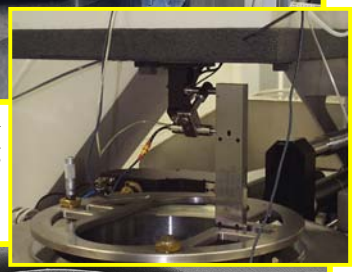
Technology/Capabilities

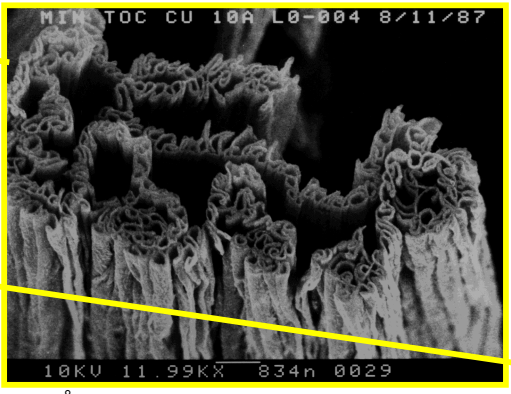
- *Machine & Instrument Design*
  - FEA for precision applications
  - Thermal system management
  - Exact constraint design
  - High stiffness design
  - Error budgeting
- *Metrology*
  - Machine tool metrology
  - Dimensional metrology
  - Surface metrology
  - Data acquisition & filtering
- *Process Development*
  - Precision turning processes
  - Grinding applications
  - Measurement tools
  - Industrialization of processes
- *Fabrications*
  - Precision
  - Optical fabrications
  - Micro-machining



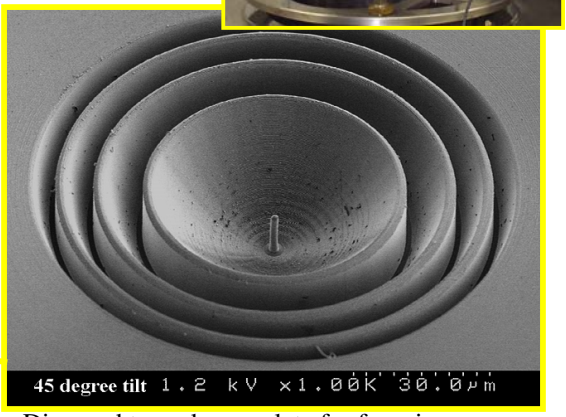
EUVL projection optics box

Precision Inspection Shell Measuring Machine





30 Å depth-of-cut chip from diamond tool



Diamond turned zone plate for focusing x-rays

Our primary mission is to support LLNL's physics programs. However, we try to maintain an array of non-DOE work too. The projects described on the following pages exemplify the diversity of our customers and the application of the above technologies.

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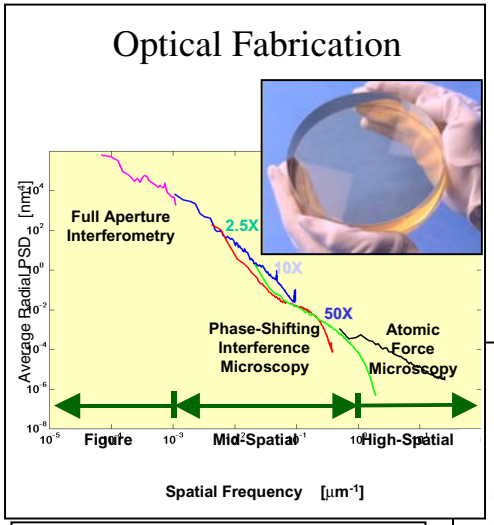
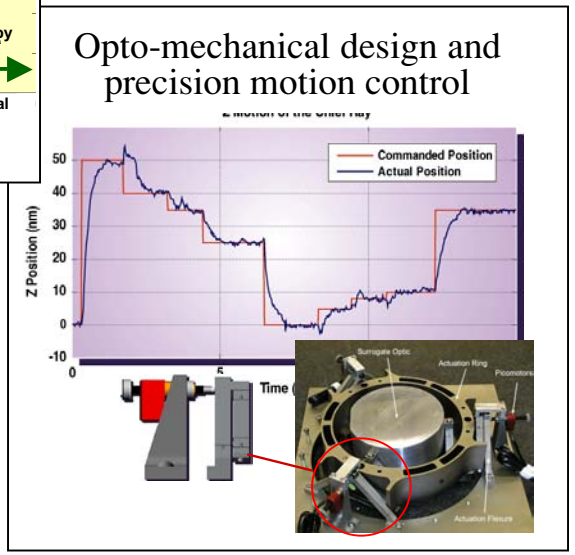
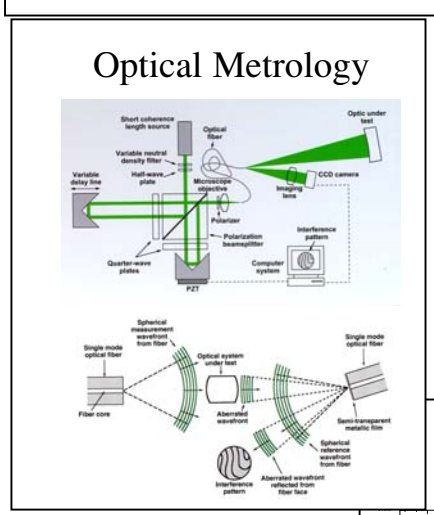
Extreme Ultraviolet Lithography (EUVL)

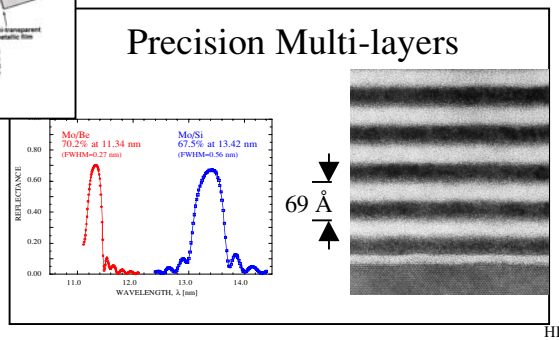
- EUVL is the surviving technology of a competition to determine the technology path for the next generation of chip fabrication. The system uses 13.4-nm light with normal incidence reflective optics.
- The cooperative project with private industry was supported by LLNL, LBNL, and Sandia. LLNL's responsibility was the imaging optical system that reduces the mask's pattern by 4x to the wafer plane.
- The technologies shown at the right all contributed to the success of the imaging system.
- The optics were fabricated, coated and installed with errors below the 0.25-nm rms figure tolerance. The system wavefront error, measured with a Phase Shifting Diffraction Interferometer, was below 5-nm rms.
- This technology is being developed for commercial use by the chipmakers and tool manufacturers.



Rendering of the EUV Lithography tool.

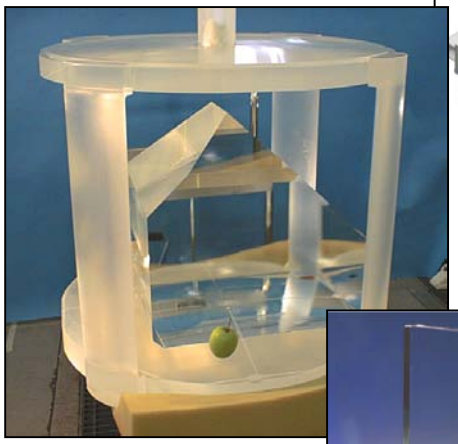


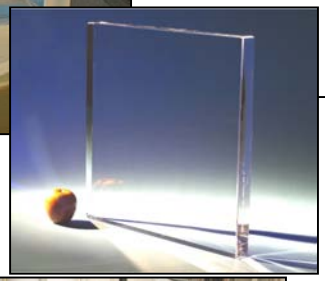




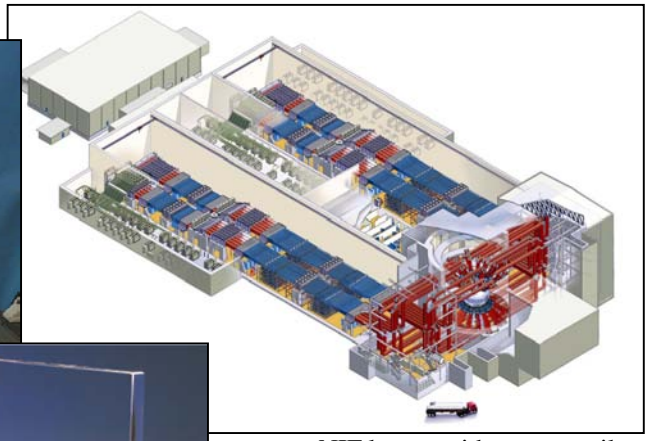
National Ignition Facility KDP Crystal Finishing

- The National Ignition Facility (NIF) is a 192-beam laser facility for studying High Energy Density Physics and Inertial Confinement Fusion.
- Potassium Di-phosphate (KDP) crystals are used in the laser systems for frequency conversion of the laser light. The crystals are 42-cm square by 1-cm thick and must have constant thickness to _/2 and surface finish better than 2-nm rms.
- We developed the machines and diamond flycutting processes to fabricate the required 800+ crystals for NIF operation. The manufacturing is done in a line of 5 machines from bandsawing the crystals from the boule to the finish cuts.
- One of the machines, shown at right, was designed and built at LLNL. The special feature of the machine is the tip-tilt-z stage shown at far right, which allows 50-nm z-motion control on 3 separate feet.

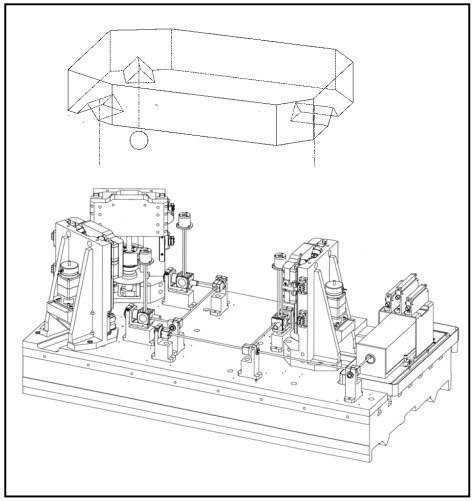




KDP boule (above) and optic (right)



NIF layout with tractor trailer (bottom) shown for scale



KDP Semi-finishing machine (above) and tip/tilt/piston platform (right).

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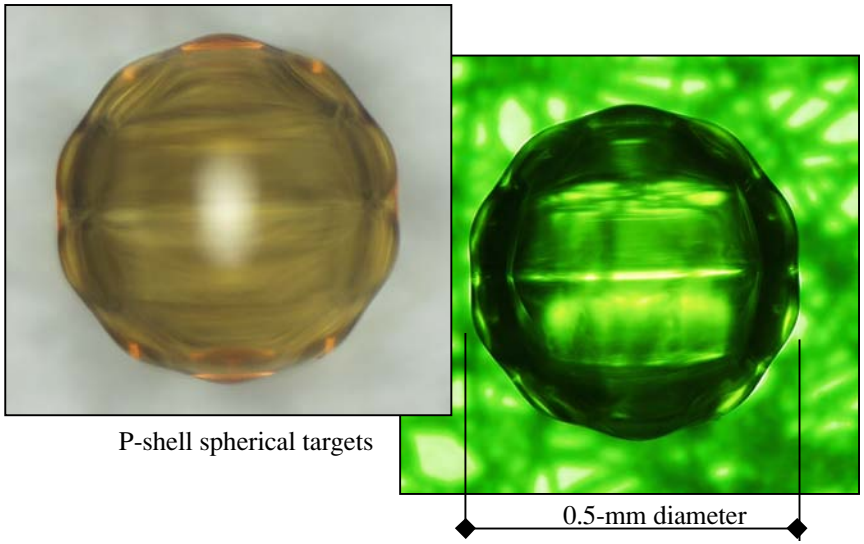
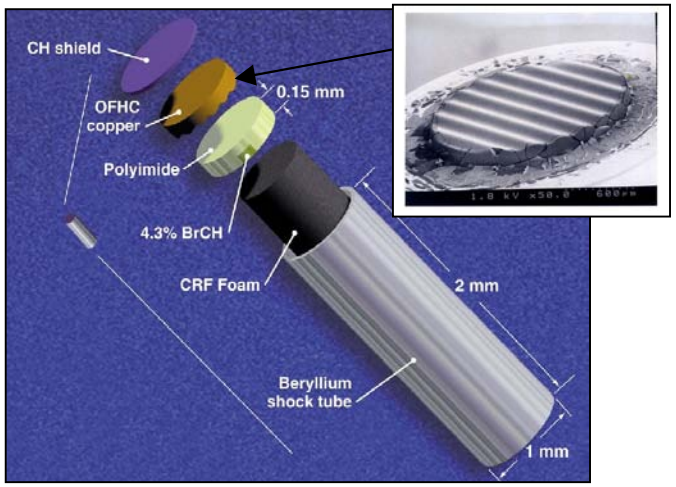
Fabrication of Targets for High Energy Density Physics Experiments

- Experiments in High Energy Density Physics are conducted on the Omega Laser in Rochester, NY and, in the future, on the National Ignition Facility at LLNL.
- The laser targets for these experiments are millimeter scale assemblies comprising components with micron-scale features.
- Some targets are spherical in nature, such as the target in the upper pictures. This target is a 0.5-mm diameter plastic over glass shell in which we diamond-machined 16-micron P-V sinusoids.Other targets are cylindrical-planar, such as the schematic assembly shown at the right.
- One of the difficulties of this work is the number of assemblies to be built per year, very few of the same design.
- Key to the future success of this business will be the development of new tools in metrology, material removal and addition, non-destructive characterization, and material development.



P-shell spherical targets



Generic target assembly – cylindrical/planar type

Mission for Precision Engineering at LLNL

Precision engineering has been a critical element in the success of LLNL's physics programs for the past 40-years. Our role has been (and will be) to bring our precision engineering tools to bear in turning the ideas of experimental physicists into reality. Those tools will also synergistically enable other nationally important science and government endeavors outside of the usual LLNL purview.

Our first mission is to support our LLNL physics programs. However, we are always looking for opportunities to apply our tools to other nationally important programs.